Component of Statistics Canada Catalogue no. 82-003-X
Health Reports

Article

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January, 2014

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..	not available for a specific reference period
...	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category ($p < 0.05$)

Impact of accelerometer epoch length on physical activity and sedentary behaviour outcomes for preschool-aged children

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Abstract

Background

The Canadian Health Measures Survey uses accelerometry to collect physical activity and sedentary behaviour data. Between cycles 2 and 3, a transition was made from 60-second to 15-second epochs in accelerometry data for children aged 3 to 5. This study examines the impact of epoch length on physical activity and sedentary behaviour outcomes.

Data and methods

Twenty-nine children aged 3 to 5 wore two accelerometers at the same time, one initialized to collect data in 60-second epochs, and the other, in 15-second epochs. Comparisons between epoch settings were made for several physical activity variables.

Results

Compared with the 60-second epoch setting, the 15-second setting captured more moderate-to-vigorous physical activity (MVPA) and sedentary time, but fewer steps and less light and total physical activity. The correlation between epoch settings was high for all variables except steps.

Interpretation

The epoch length used in accelerometer data collection affects physical activity and sedentary behaviour data for preschool-aged children.

Keywords

Ambulation, pediatric, stepping, walking

Authors

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The Canadian Health Measures Survey (CHMS) uses accelerometry to directly measure physical activity and sedentary behaviour. Accelerometers record movement data at defined intervals called "epochs." The epoch length used in research ranges from less than one second to one minute.

The use of accelerometry to measure physical activity among preschool-aged children presents unique challenges because their movement is more sporadic and intermittent than that of older children and adults.[1] Research has shown that collecting accelerometer data in shorter rather than longer epochs captures more moderate-to-vigorous physical activity (MVPA) in young children. As a result, the use of longer epoch lengths for this population has been questioned. A consensus is emerging that shorter epochs should be used for preschool-aged children to ensure that short bursts of movement are recorded.[2-4]

Determination of MVPA levels among preschool-aged children is important because MVPA is a component of new guidelines that recommend 180 minutes a day of physical activity of any intensity for 0- to 4-year-olds, with a progression toward 60 minutes of MVPA by age 5.[5] Obeid et al. found that, when compared with 3-second epochs, the use of 15-, 30- and 60-second epochs resulted in averages of 2.9, 9.0 and 16.7 "missed" minutes of MVPA per day, respectively.[3] Another study reported 17 minutes more MVPA a day when accelerometer data were recorded in 5-second rather than 60-second epochs.[4]

Cycle 2 (2009 to 2011) CHMS data, collected in 60-second epochs, indicate that the majority (84%) of of children aged 3 to 5 meet meet the guideline of 180 minutes a day of physical activity of any intensity.[6] How this estimate would have differed had a 15-second epoch setting been used is not known. No published research has examined the comparability of physical activity data based on 15- and 60-second epochs using the Actical® accelerometer.

Although *reintegration* of epoch data—converting data collected in shorter epochs to longer epochs—is relatively common,[3,7] concern has been

The article " Impact of accelerometer epoch length on physical activity and sedentary behaviour outcomes for preschool-aged children " was updated April 9th, 2014. The changes affect the data source of tables and figures and the addition of an acknowledgments section.

raised about this approach.[8] For example, Edwardson et al. reintegrated data collected in 5-second epochs to 15-, 30-, and 60-second epochs.[9] They found a significant effect of epoch length and concluded that data collected in 5-second versus 60-second epochs should not be compared.[9] Using similar methodology, Nilsson et al. found no difference in moderate-intensity activity, but a difference in vigorous-intensity activity, when shorter epochs (5-, 10-, 20-, 40-second) were reintegrated into 60-second epochs.[10] Researchers who have published physical activity intensity cut-points have also advised against converting cut-points developed for a particular epoch to another epoch. Pfeiffer et al. published 15-second cut-points for preschool children and cautioned against multiplying those cut-points by 4 to derive cut-points for data collected in 60-second epochs.[11]

Although cycle 2 of the CHMS collected data for 3- to 5-year-olds in 60-second epochs, to conform with the emerging consensus about the desirability of using shorter epochs for young children, the CHMS transitioned to 15-second epochs for this age group in cycle 3. The primary purpose of this study is to assess the degree to which Actical® accelerometer data collected in 60- versus 15-second epochs differ for children aged 3 to 5 by comparing derived physical activity variables from data collected in both 15- and 60-second epochs. The analysis also examines how 60- and 15-second epoch data compare with 15-second epoch data that were reintegrated into 60-second data. A secondary analysis was performed to determine how differences in epoch length affect the classification of young children according to current Canadian physical activity guidelines.[5]

Data and methods

Participants

A convenience sample of 32 preschool-aged children who were part of a physical activity in daycare research study wore two Actical® (Phillips – Respironics, Oregon, USA) accelerometers side-by-side on a belt around their waist for a week. One Actical® was initialized to collect data in 15-second epochs, and the other, in 60-second epochs. Written informed consent was obtained from parents. The study protocol was approved by the Children's Hospital of Eastern Ontario Research Ethics Board.

Data collection

The children wore both accelerometers over their right hip on an elasticized belt during their waking hours for seven consecutive days. The Actical® (dimensions: 2.8 x 2.7 x 1.0 centimetres; weight: 17 grams) measures and records time-stamped acceleration in all directions, providing an index of physical activity intensity. The digitized values are summed over a user-specified interval, resulting in a count value per unit time (counts per 15 seconds versus counts per 60 seconds). Accelerometer signals are also recorded as steps per unit time. The Actical® has been validated to measure physical activity in preschool-aged children, and physical activity intensity cut-points have been developed for this age group.[7,11] The monitors were initialized to start collecting data at the first occurrence of midnight following the day the monitors were given to the child. The data were blind to participants while they wore the devices.

Data cleaning

All children with at least one valid day of data were included in this analysis. A valid day was defined as a minimum of five hours of wear time, with non-wear time defined as a period of at least

Table 1
Mean accelerometer results from 60-, 15- and reintegrated 15-second epoch settings

	60-second epoch data				15-second epoch data				15-second epoch data reintegrated to 60-second epoch data			
			Range				Range				Range	
	Mean	SD	from	to	Mean	SD	from	to	Mean	SD	from	to
Wear time (hours per day)	11.19	1.81	5.12	16.68	11.39*	1.96	5.11	17.59	11.15†	1.89	5.13	16.68
Total counts per day	230,620	78,923	60,563	559,118	226,585	75,951	62,493	493,327	226,528†	75,968	62,389	493,327
Total physical activity (minutes per day)	324.39	70.96	138.00	568.00	259.49**	59.71	103.25	430.50	322.84†	72.00	141.00	550.00
MVPA (minutes per day)	51.56	25.55	7.00	149.00	56.19**	21.73	11.00	134.00	50.43†	24.14	9.00	128.00
Light physical activity (minutes per day)	272.83	58.06	123.00	419.00	203.29**	45.36	92.25	329.50	272.41†	59.45	128.00	422.00
Sedentary time (minutes per day)	346.77	89.72	169.00	666.00	424.17**	101.10	202.50	751.25	346.03†	96.44	145.00	696.00
Steps per day	10,071	4,025	2,673	21,345	9,100*	3,854	1,337	18,611	9,100*	3,854	1,337	18,611

MVPA = moderate-to-vigorous physical activity
SD = standard deviation
Total physical activity = MVPA + light physical activity
* significantly different from 60-second epoch data, $p < 0.05$
** significantly different from 60-second epoch data, $p < 0.0001$
† significantly different from 15-second epoch data, $p < 0.0001$
Source: Preschooler Activity Trial

60 consecutive minutes of zero counts.[12] Physical activity intensity cut-points were applied to the data to determine the amount of time in each intensity category: sedentary, light and MVPA. The sedentary-to-light cut-points were 100 counts per minute (cpm) for 60-second epoch data and 25 counts·15sec^{-1} [13]; the light-to-moderate cut-points were 1,150 cpm and 288 counts·15sec^{-1}, respectively.[7] Total steps accumulated were summed per day for the 15-second and 60-second epoch data. Fifteen-second data were used as is, and also reintegrated into 60-second epochs by summing every four observations.

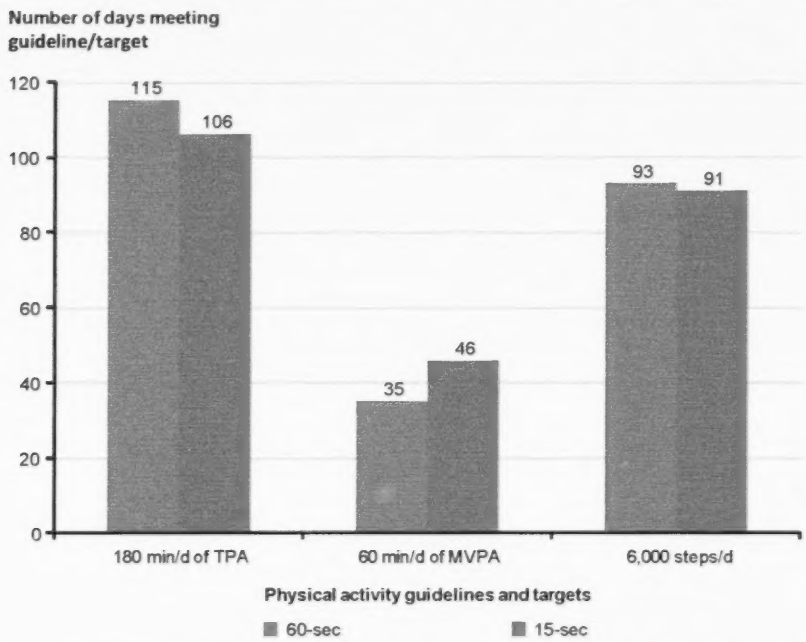
The initial dataset contained 5 days of data on 32 children (potential for 160 days). Days 6 and 7 were deleted from the 60-second epoch dataset because the 15-second epoch setting allows for only 5.5 days of memory. Two participants had no valid data recorded, and for another participant, the valid days available did not match between epoch settings. Thirty-four days were deleted from the dataset because they were invalid for all epoch types. A further 2 days were deleted because they were invalid for the 60-second epoch setting, and 2 days were deleted because they were invalid for the 15-second epoch setting. Therefore, the final analysis was completed on 118 days. The average number of valid days per participant was 4.1, with a range between 1 and 5 days.

Table 2
Regression equations and R^2 values for association between 60- and 15-second epoch data for physical activity and sedentary behaviour outcome variables

	Regression equation (x = 60-second epoch, y = 15-second epoch)	R^2
Wear time (hours per day)	y = 1.04x + 1.09	0.91
Total counts per day	y = 0.79x + 4.54	0.87
Total physical activity (minutes per day)	y = 0.91x + 17229.07	0.89
MVPA (minutes per day)	y = 0.78x + 15.76	0.85
Light physical activity (minutes per day)	y = 0.72x + 6.67	0.85
Sedentary time (minutes per day)	y = 1.03x + 67.20	0.83
Steps per day	y = 0.26x + 6438.22	0.08

MVPA = moderate-to-vigorous physical activity
Total physical activity = MVPA + light physical activity
Source: Preschooler Activity Trial

Figure 1
Number of days out of possible 118 meeting three physical activity targets for 60- and 15-second epoch data



steps/d = steps per day
min/d = minutes per day
TPA = total physical activity
MVPA = moderate-to-vigorous physical activty
Source: Preschooler Activity Trial

Data analysis

Data for 1 boy and 2 girls were removed because of a lack of any valid days. The analysis was based on information collected from 12 boys and 17 girls (n=29). Their average age was 3.61 (± 0.71) years; their average weight was 16.07 (± 2.46) kg; and their average height was 99.55 (± 6.57) cm. The average body mass index of the sample was 16.15 (± 1.04) kg·m^{-2}. There was one missing value in the calculation of average age because parents did not provide date of birth.

Comparisons were made using paired t-tests between 60-, 15- and reintegrated 15-second epoch data for the following variables: wear time, total counts per day, total physical activity, MVPA, light physical activity, sedentary time, and step counts per day. Correlation and linear regression analysis were used to examine the strength of association between 15-second and 60-second epoch data for all physical activity and sedentary behavior variables. One outlier was removed in the step-count analysis, because it was greater than three standard deviations from the mean. Data were ana-

lyzed using SAS (Version 9.2). The data reduction procedures were harmonized with previous Canadian Health Measures Survey physical activity papers.[14-16]

Results

Descriptive data

Table 1 presents descriptive data on the 60-second, 15-second and reintegrated 15-second epoch data for several accelerometer outcome variables. Compared with 15-second epoch data, 60-second epoch data captured less wear time (-0.20 h·d^{-1}), MVPA (-4.63 min·d^{-1}) and sedentary time (-77.4 min·d^{-1}), but more daily step counts (+971 steps·d^{-1}), light (+69.54 min·d^{-1}) and total physical activity (+64.90 min·d^{-1}).

No statistically significant differences emerged between 60-second and reintegrated 15-second data, except for step counts per day (+971 steps·d^{-1}). Less total (-63.35 min·d^{-1}) and light physical activity (-69.12 min·d^{-1}) was captured in 15-second epoch data, compared with reintegrated 15-second data. More wear time (+0.24 h·d^{-1}), total counts per day (+57 counts·d^{-1}), MVPA (+5.76 min·d^{-1}) and sedentary time (+78.14 min·d^{-1}) were captured in 15-second epoch data. There was no difference in average daily step counts between 15-second data and reintegrated 15-second data.

Correlation and linear regression analyses

The correlations between 15-second and 60-second epoch data were high (Rho > 0.9, $p < 0.0001$) for wear time, total counts per day, sedentary time, light physical activity, total physical activity and MVPA. The correlation was weaker, but still significant, for step counts (Rho = 0.28, $p = 0.002$).

Based on the regression equation in Table 2, 30 minutes of MVPA on a 60-second epoch setting is equivalent to 39 minutes of MVPA on a 15-second epoch setting. The absolute difference decreases as average minutes of MVPA increase. For example, 60 minutes of MVPA on a 60-second epoch setting is equivalent to 62.5 minutes of MVPA on a 15-second setting. At around 70 minutes of MVPA, the difference disappears, and thereafter, the 15-second epoch setting has lower MVPA values than the 60-second epoch setting.

A weaker association was observed (R^2 = 0.08) between 15-second and 60-second epoch data for daily step counts. Based on the regression equation in Table 2, 5,000 steps per day on a 60-second epoch setting would be equivalent to approximately 7,600 steps per day on a 15-second epoch setting. The absolute difference is lowest between 8,000 and 9,000 steps per day (for example, 8,500 steps per day on a 60-second epoch setting = 8,685 steps per day on a 15-second epoch setting). Beyond this point, there would be fewer daily steps in 15-second data than in 60-second data.

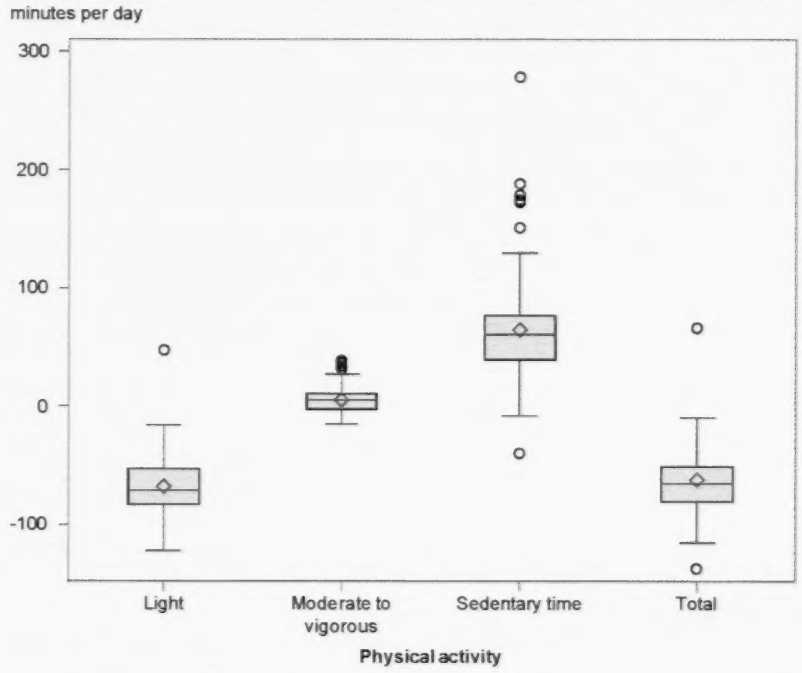
Meeting the guideline

The guideline for 0- to 4-year-olds—a total of 180 minutes of physical activity per day—was met on more days in 60-second epoch data (97.5% of days) than in 15-second epoch data (89.8% of days) (Figure 1). The 60-minutes-of-MVPA-per-day target was met on more days in 15-second epoch data (39.0% of days) than in 60-second epoch data (29.7% of days). The step-count target (6,000 steps per day) was met on a similar number of days in 60-second and 15-second epoch data (78.8% and 77.1% of days, respectively).

Individual day differences

The ranges in differences between 15-second and 60-second epochs are presented in boxplots for light physical activity, MVPA, sedentary time, total physical activity (Figure 2) and daily step counts (Figure 3). The differences

Figure 2
Absolute differences in physical activity and sedentary behaviour outcome variables between 15- and 60-second epoch data



Notes: Diamond represents the mean, the line through the box, the median. The bottom and top lines represent the 25th and 75th percentiles. Whiskers represent 1.5 times the inter-quartile range. Circles are outliers falling outside that range.
Source: Preschooler Activity Trial

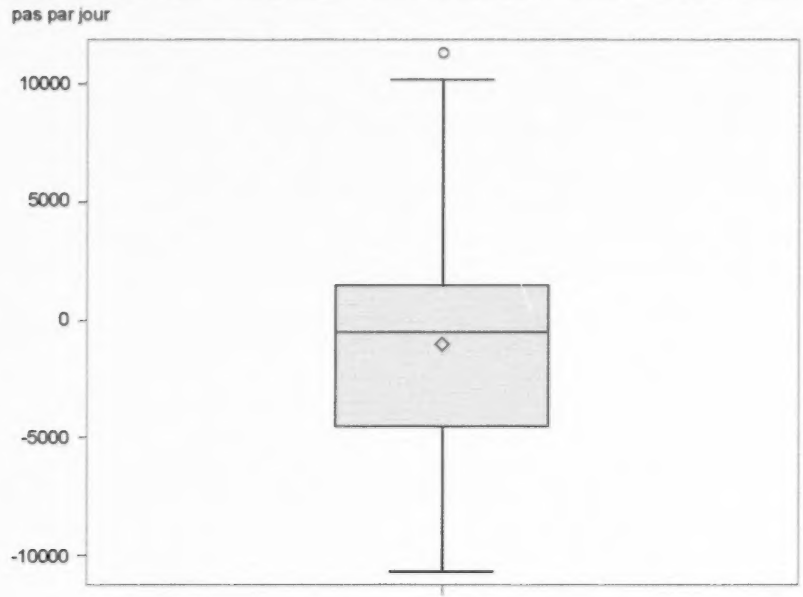
between 60-second and 15-second data ranged from -123 to +48 min·d^{-1} for light physical activity, from -15 to +36 min·d^{-1} for MVPA, from -40 to +279 min·d^{-1} for sedentary time, and from -137.5 to +66.5 min·d^{-1} for total physical activity (Figure 2). Forty-one days (34.7%) were within ±10% of mean daily MVPA, based on 60-second epochs (data not shown). The difference in daily step counts between 60-second and 15-second data ranged from -10,675 to +11,347 steps per day (Figure 3). Twenty-one days (17.8%) were within ±10% of mean daily step counts per day, based on 60-second epochs (data not shown).

Discussion

Consistent with previous research, this study found that shorter epochs for data collection (15-second) captured more MVPA than did longer epochs (60-second). The shorter epochs also captured more sedentary time, but less light and total physical activity. The strong associations between 15-second and 60-second epochs for all accelerometer outcomes (MVPA, total physical activity, sedentary time) suggest that making comparisons between epoch settings is realistic for these outcome variables. However, marked differences between 15-second and 60-second epoch data for daily step counts signal a need for caution when comparing step-count data collected at different epoch settings.

The differences between epoch settings have important implications for users of CHMS data who wish to compare cycle 2 and cycle 3 physical activity and sedentary behaviour levels of 3- to 5-year-olds. Specifically, because of the change in epoch length, apparent *increases* or *decreases* in physical activity levels should be greater than the difference that would be expected to result from this change.

Figure 3
Absolute differences in daily step counts between 15- and 60-second epoch data



Notes: Diamond represents the mean; the line through the box, the median. The bottom and top lines represent the 25th and 75th percentiles. Whiskers represent 1.5 times the inter-quartile range. Circle is outlier falling outside that range.
Source: Preschooler Activity Trial

The finding that shorter epochs capture more MVPA but less total physical activity (MVPA + light physical activity) in preschool-aged children is consistent with other studies.[3,4] The 60-second epoch setting captured an average of 64.9 more minutes of total physical activity than did the 15-second epoch setting, which is similar to a 72.6-minute difference between 15-second and 60-second epochs observed previously.[3] Obeid et al. speculated that this reflected the displacement of some sedentary time to light physical activity when using longer epochs.[3] To illustrate, a short burst of activity within a minute of sedentary time would be categorized as light intensity using 60-second epochs, as opposed to 45 seconds of sedentary time and 15 seconds of light or moderate intensity activity using 15-second epochs. Confirming this theory would require a direct observation study, but it seems plausible and helps to explain the findings of both studies.

Whereas total physical activity, MVPA, light physical activity and sedentary time were highly correlated between 15-second and 60-second epochs (Table 2, all $R^2 > 0.8$), a different pattern was observed for daily step counts (Table 2, $R^2 = 0.08$). The average difference between 15-second and 60-second epoch data was 971 steps per day; when individual days were examined, the difference was as great as ±10,000 steps per day (Figure 3). However, the ability of accelerometers and pedometers to accurately capture step counts in preschool-aged children has been questioned. For example, Rosenkranz et al. found a weaker association between step counts and a criterion measure of steps (direct observation) among shorter children compared with taller children.[17] Similarly, another study found that the correlation between step counts and MVPA was lower in 3-year-olds (Rho = 0.19, $p < 0.19$) than in 4- and 5-year-olds (Rho = 0.50, $p < 0.001$).[18] The ability of pedometers and accelerometers to capture steps during slow walking, crawling or playing—common movements among

very young children—has also been questioned.[17,19-21] Together, the limitations in measuring step counts in preschool-aged children help to explain the poor agreement between 15-second and 60-second epoch lengths. The majority of children in the present study were 3-year-olds, which may have contributed to the especially low correlation between daily step counts collected in 15-second versus 60-second epochs. It is also possible that 15-second epochs may miss steps that are in progress when an epoch is transitioning. A 60-second epoch may result in fewer missed steps because of less stopping and starting of the monitor's step-counting function.

What is already known on this subject?

- The use of accelerometry to measure physical activity among preschool-aged children presents unique challenges because their movement is more sporadic and intermittent than that of older children and adults.
- Research has shown that recording accelerometer data in shorter epochs (intervals) in young children captures more moderate-to-vigorous physical activity, which is a component of the new physical activity guidelines for children aged 0 to 4.

What does this study add?

- A convenience sample of 29 preschool-aged children wore two Actical® accelerometers side-by-side on a belt around their waist for a week.
- Compared with 15-second epoch data, 60-second epoch data recorded less moderate-to-vigorous physical activity and sedentary time, but more daily step counts, light activity and total physical activity.

The high correlation between epoch settings for total physical activity, MVPA, light physical activity and sedentary time makes between-cycle and between-epoch-length comparisons feasible. By contrast, the marked differences in step counts between epoch lengths suggests that direct comparisons of step counts between CHMS cycles are problematic.

The regression equations in Table 2 can be used to estimate the extent to which the epoch-length difference between CHMS cycles 2 and 3 contributes to observed differences in average daily minutes of total physical activity, MVPA, light physical activity and sedentary time. Assuming a similar level of activity in the population, cycle 3 data (collected and analyzed in 15-second epochs) would be expected to show a slightly higher percentage of children meeting the guideline of 180 minutes a day of physical activity of any intensity, and a slightly lower percentage meeting the guideline of 60 minutes a day of MVPA. Cycle 2 data, collected in 60-second epochs, indicate that 84% of preschool-aged children meet the guideline of 180 minutes of physical activity a day.[6] Because the present study was analyzed on a per-day basis, rather than a per-person basis, it is difficult to assess how the 29 children in the study compare with the national sample. However, 97.5% of days met the guideline when 60-second epochs were used, indicating a similarly high level of adherence.

The results of this study suggest that the CHMS cycle 2 estimate of 84% meeting the guideline might have been lower had a 15-second epoch setting been used. Therefore, if a lower estimate is obtained in cycle 3 (15-second epoch data collection), the change should not be interpreted as an decrease in population levels of physical activity. This analysis implies that the difference is likely due to the methodological change. However, the results of this study do not provide clear direction on how to interpret observed differences between CHMS cycles in daily step counts.

Reintegration of accelerometer data from shorter to longer epochs is common.[3,7] In the present study, when 15-second data were re-integrated into 60-second data, the additional MVPA captured by the shorter epochs was lost. An average of 56 minutes of MVPA was captured in 15-second data versus 51 minutes in 60-second data and in 15-second re-integrated data (Table 1). The other accelerometer outcomes followed this trend, with minor differences between re-integrated 15-second data and 60-second data. By contrast, the step counts obtained from 15-second data (re-integrated or not) were the same, and both were less than the step counts accumulated in 60-second epochs. If the assumption that shorter epochs are optimal in very young children is accepted, the reintegration results demonstrate that applying 15-second cut-points to 15-second resolution data is better than converting 15-second data into 60-second data and applying cut-points that are in count-per-minute resolution.

The present analysis offers practical recommendations to those working with CHMS accelerometry data. The regression equations in Table 2 provide a mechanism to estimate what the physical activity results would have been had the other epoch setting been used. Step-count data should be interpreted with caution, because the results indicate that data collected in 15-second and 60-second epoch settings are not comparable.

The small sample size precluded age and sex breakdowns, and may limit the overall analysis and generalizability. In addition, the sample consists of 3- to 5-year-olds and does not reflect activity among younger children whose gait patterns are even less developed.

The study highlights a need for further work to clarify the optimal epoch length for capturing step counts for very young children. In fact, research is needed to determine if accelerometers and pedometers can capture the unique nature of how children this young accumulate steps. It is possible that step-count data are inappropriate for this age group, whose gait patterns are not as consistent and predictable as those of older children and adults. It is likely that studies incorporating an

alternative criterion measure, such as direct observation, will be required for this age group. Previous observations of older children demonstrated that accelerometry and direct observation yield comparable estimates of MVPA, and that shorter epochs provide a closer estimate than do longer epochs.[22] As accelerometry technology evolves and epochs get shorter, further exploration of the impact of epoch length on physical activity and sedentary behaviour outcomes will be needed. Consensus is emerging that shorter is better when it comes to epoch length in very young children, but whether there is a point at which going lower makes no substantive difference to the outcomes is unknown.

Conclusion

The CHMS transition from 60-second to 15-second epochs in accelerometer-measured physical activity data for preschool-aged children is consistent with the direction of the research community. However, when such a methodological change occurs, analytical questions arise. The present study found that epoch length affects physical activity and sedentary behaviour data, and provides practical recommendations on how to interpret differences between the two cycles of the survey. ■

Acknowledgments

The authors wish to acknowledge the Heart & Stroke Foundation and the Ontario Ministry of Research and Innovation (ER08-05-147) for funding the project. The authors also wish to acknowledge Dr. Gary Goldfield (principal investigator on the Preschooler Activity Trial).

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